IDENTIFICATION OF FRESH FELDSPARS IN GALE CRATER USING CHEMCAM. P. J. Gasda[1], D. M. DeLapp[1], R. E. Mcinroy[1], R. C. Wiens[1], J. C. Bridges[2], P. H. Edwards[2], E. Carlson[3], V. Sautter[4], A. Cousin[4], S. Maurice[4], O. Gasnault[4], S. Clegg[1], and the MSL team [1]Los Alamos National Laboratory (gasda@lanl.gov), NM [2]University of Leicester, UK [3]New Mexico Institute of Mining and Technology, NM [4]IRAP/CNRS

Introduction: Felsic float rocks and clasts within conglomerates have been identified by the Mars Science Laboratory (MSL) by identifying targets with MastCam images and then considering the ChemCam data of the target [1,2,3] or with blind clustering techniques that consider ChemCam data [4]. Felsic float rocks in Gale Crater are mainly found in the Bradbury formation, indicating that the rocks were likely erosional detritus brought down via valley networks along the crater rim (e.g., Peace Valles [5]) or implaced by impact processes. The ubiquity of felsic float rocks from Peace Valles indicate a rich source region of felsic materials in the northern crater rim, and may also be an indication of a felsic component in the ancient Southern Highlands crust [2].

The goal of this work is to identify and study the fresh and large feldspars sampled by the ChemCam instrument. Feldspars are important tracers of conditions within magma chambers, including chemical evolution and differentiation. The investigation of the fresh feldspars will shed light on the diversity of martian volcanism and the evolution of the felsic component in the ancient Southern Highlands crust.

Methodology: ChemCam is a combination remote laser-induced breakdown spectroscopy (LIBS) and micro imager (RMI) instrument [6,7]. The typical ChemCam measurement consists of multiple observation points on a target separated by a few mm with 30 laser shots per point. Using a combination of partial least squares and independent component analysis multivariate methods, the major-element oxide abundances were extracted from the ChemCam LIBS spectra [8] for both the average spectra of a point (minus the first 5 shots dominated by dust) and for the individual shot spectra.

The feldspar identification analysis is performed by a custom program written in Mathworks MATLAB 2015a software. The average major-element oxide data up to sol 1033 for the best spectra is first broadly filtered for feldspars (e.g., discarding points with too much FeO+MgO). The filtered targets are then converted to atomic proportions to check the stoichiometry of each filtered point (no normalization to 100). MastCam [9] and RMI images are used to asses target context and to discard bad points (e.g., soils and out-of-focus points).

To identify the fresh and large feldspar targets, An# (anorthite number) is plotted against Al/Si ratio for the single shot data. In feldspars, An# is the measure of Ca, and An# must be proportional to Al/Si. Al/Si varies from 0.33–1 depending on the Ca content of the feldspar. If Al is increasing without an increase of Ca, it is an indication of alteration or of a non-feldspar grain. If Ca is increasing without Al, then this could indicate the depth profile is entering a calcium-rich mineral phase other than feldspar.

To aide in the interpretation of the single-shot data, both simulated and laboratory experiments were used. Simulated mineral major-element oxide data with compositions similar to feldspars (e.g., feldspathoids) were run by the MATLAB routine to test its ability to discard non-feldspars. Laboratory experiments were performed using the ChemCam engineering model located at LANL. Samples include endmember feldspars (LANL and Shiv Sharma, Univ. Hawai‘i), a trachyte (Southern CO; Scott Muggleton), 2 trachybasalts (Mt Dore, Auvergne, France and Mt Kilimanjaro, Tanzania; both from Univ. Leicester collection), and a mugearite (Molokai, HI; John Sinton, Univ. Hawai‘i). Five LIBS points of 150 shots/point were performed from 1.6 m with samples in a chamber that simulates the martian atmosphere with pre- and post-LIBS background measurements. An Earth-to-Mars correction [10] is applied to these spectra to make them comparable to the Mars target LIBS spectra.

Results and Discussion: *Mars Data.* In the first 1033 sols, 122 possible feldspar points were identified (Fig 1) out of 5,724 total points. Feldspar identifications are summarized in the table in Fig 1. MastCam and RMI images of the identified targets typically show the feldspars and other minerals to be very coarse grained.

The approx. whole-rock compositions of the identified targets are calculated by averaging all the points on the host rock. The igneous targets tend to have few sub-alkaline compositions; basaltic targets tend not to have visible feldspars. Most targets are hypersthene normative, in the trachybasalt to trachyandesite range [11].

Identified targets generally agree with previous surveys of felsic float rocks found in Gale crater. Some previously identified targets (e.g., from [1]) have been excluded from our results because they did not meet our requirements, while new feldspars have been identified.

Simulated minerals. Simulations performed so far show that the data-filtering procedure did not exclude six non-feldspar minerals (Fig 1, filled circles): leucite

($KAlSi_2O_6$), analcime ($NaAlSi_2O_6 \cdot H2O$), jadeite ($NaAlSi_2O_6$), and scapolite endmembers marialite ($Na_4Al_3Si_9O_{24}Cl$) and meionite ($Ca_4Al_6Si_6O_{24}CO_3$). These simulated minerals tend to have a high Ca+Na+K cation totals (1.2–1.3) compared to the ideal (1.0). Jadeite and analcime tend to plot very close to albite, and leucite plots very close to orthoclase, but all three have high Al/Si ratios compared to what is expected for alkali feldspars (0.33). Hence, we can conclude that we are not accidentally detecting jadeite, leucite, or analcime in the Mars dataset.

Scapolites present a small problem because the scapolite solid solution plots between marialite and meionite in the same chemical space as the plagioclase feldspar solid solution. Since scapolites are a product of feldspar hydrothermal alteration (e.g., [12]), and have been detected in the martian meteorite Nakhla [13] and possibly from orbit [14], we cannot rule out the accidental detection of scapolites in our dataset.

Preliminary lab experiments. A few points in the Mars dataset have patterns that suggest zoned feldspars or mixing of multiple feldspar types, possibly indicating exsolution lamellae. Fig 2 shows three examples of possible mixtures. Our preliminary interpretation, before testing in the lab, suggests that the ChemCam laser is depth profiling through at least two feldspar grains of different composition for Togo and Union_Springs. Glidden is either a mixture of two or more feldspars smaller than the ChemCam laser spot size (500 µm) or a glassy mixture.

Three feldspar minerals, orthoclase ($KAlSi_3O_8$), albite ($NaAlSi_3O_8$), and andesine ($(Ca,Na)(Al,Si)_4O_8$), have been measured in the lab thus far. Example spectra for the three minerals (150 shot average) is shown in Fig 3 in 2 regions of the LIBS spectrum relevant to feldspars. Fig 3 shows how the interpretation of LIBS spectra of feldspars is not straightforward. For example, the peak intensity for Al in orthoclase is higher than that for andesine. The unexpected peak intensities in the spectra could be caused by matrix effects or simply that these samples may not be pure endmembers. We anticipate that the type of multivariate analyses routinely used on ChemCam data will yield accurate compositions.

Acknowledgements: We thank the NASA Mars Exploration Program and CNES, France, for support.

References: [1] Cousin et al., 2015 *46thLPSC* #2452, [2] Sautter et al., 2015 *Nat GeoSci* 8, [3] Mangold et al,. *this meeting*, [4] Gasnault et al., 2015, *46thLPSC* #2789 [5] Palucis et al., 2014, *JGR Plan.*, 119, [6] Wiens et al., 2012, *Space Sci Rev,* 170, [7] Maurice et al., 2012, *Space Sci Rev* 170, [8] Clegg et al., *in prep*, [9] Bell III et al., 2012, *43rdLPSC* #2541, [10] Boucher et al., 2015 *46thLPSC* #2773, [11] Bridges et al., *this meeting*, [12] Faryad et al., 2002 *J Petrol* 43, [13] Filiberto et al., 2014 *EPSL* 401, [14] Clark et al., 1990 *JGR Solid Earth* 95.

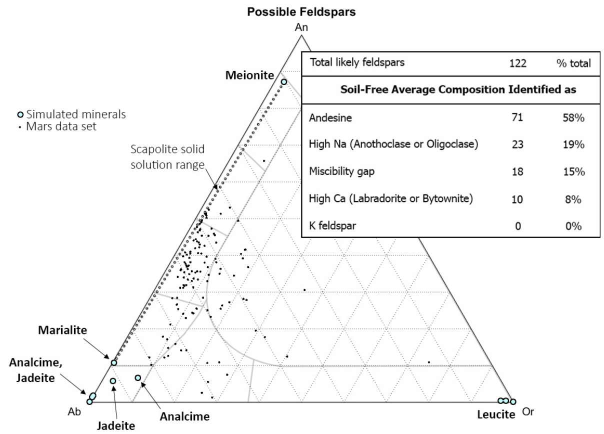

Figure 1: Possible Mars feldspars (black points) plotted on a ternary diagram and summarized in table inset, compared to simulated mineral targets (filled circles).

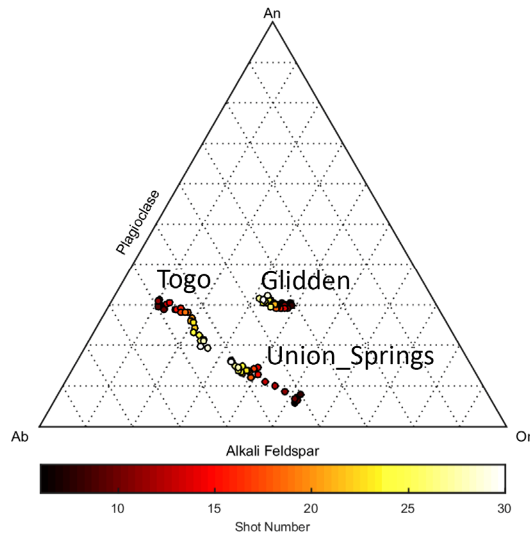

Figure 2: Three examples of single-shot spectra possibly indicating two or more feldspars. Color of the point indicates shot number.

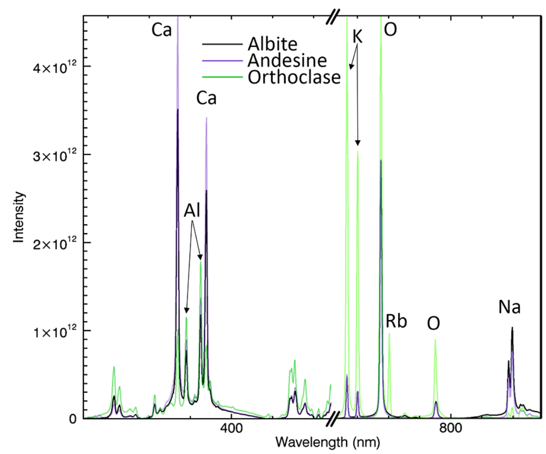

Figure 3: LIBS laboratory spectra of feldspars in relevant spectral regions.